WELLBORE GRAVEL PACKING APPARATUS AND METHOD

[0001] This application claims the benefit of U.S. Provisional Application 60/562,521 filed on December 3, 2003.

Field of the Invention

[0002] This invention relates generally to a wellbore apparatus and method for using the apparatus in a wellbore. More particularly, this invention relates to wellbore completion utilizing a wellbore apparatus suitable for gravel packing and production of hydrocarbons.

Background

[0003] In the production of hydrocarbons from hydrocarbon-bearing unconsolidated formations, a well is provided which extends from the surface of the earth into the unconsolidated or poorly consolidated formation. The well may be completed by employing conventional completion practices, such as running and cementing casing in the well and forming perforations through the casing and cement sheath surrounding the casing, thereby forming an open production interval which communicates with the formation.

[0004] Hydrocarbon production from subterranean formations commonly includes a wellbore completed in either cased hole or open-hole condition. In cased-hole applications, a wellbore casing is placed in the wellbore and the annulus between the casing and the wellbore is filled with cement. Perforations are typically made through the casing and the cement into the production interval to allow formation fluids (such

as, hydrocarbons) to flow from the production interval zones into the casing. A production string is then placed inside the casing, creating an annulus between the casing and the production string. Formation fluids flow into the annulus and then into the production string to the surface through tubing associated with the production string. In open-hole applications, the production string is directly placed inside the wellbore without casing or cement. Formation fluids flow into the annulus between the formation and the production string and then into production string to surface.

[0005] The production of hydrocarbons from unconsolidated or poorly consolidated formations may result in the production of sand along with the hydrocarbons. Produced sand is undesirable for many reasons. It is abrasive to components within the well, such as tubing, pumps and valves, and must be removed from the produced fluids at the surface. Further, it may partially or completely clog the well, thereby requiring an expensive workover. In addition, the sand flowing from the formation may leave a cavity, which may result in the formation caving and collapsing of the casing.

[0006] A technique commonly employed for controlling the flow of sand from an unconsolidated or poorly consolidated formation into a well involves the forming of a gravel pack in the well adjacent part or all of the unconsolidated or poorly consolidated formation exposed to the well. Thereafter, hydrocarbons are produced from the formation through the gravel pack and into the well. Gravel packs have generally been successful in mitigating the flow of sand from the formation into the well.

[0007] Several downhole solid, particularly sand, control methods being practiced in industry are shown in Figures 1(a), 1(b), 1(c) and 1(d). In Figure 1(a), the production string or pipe (not shown) typically includes a permeable outer member (such as, a sand-screen or sand control device) **1** around its outer periphery, which is placed adjacent to each production interval. The sand-screen prevents the flow of sand from the production interval **2** into the production string (not shown) inside the sand-screen **1**. Slotted or perforated liners can also be utilized as sand-screens or sand control devices. Figure 1(a) is an example of a screen-only completion with no gravel pack present.

[0008] As discussed above, one of the most commonly used techniques for controlling sand production is gravel packing wherein sand or other particulate matter is deposited around the production string or well-screen to create a downhole filter. Figures 1(b) and 1(c) are examples of cased-hole and open-hole gravel packs, respectively. Figure 1(b) illustrates the gravel pack **3** outside the screen **1**, the wellbore casing **5** surrounding the gravel pack **3**, and cement **8** around the wellbore casing **5**. Typically, perforations **7** are shot through the wellbore casing **5** and cement **8** into the production interval **2** of the subterranean formations around the wellbore. Figure 1(c) illustrates an open-hole gravel pack wherein the wellbore has no casing and the gravel pack material **3** is deposited around the wellbore sand-screen **1**.

[0009] A variation of a gravel pack involves pumping the gravel slurry at pressures high enough so as to exceed the formation fracture pressure ("Frac-Pack"). Figure 1(d) is an example of a Frac-Pack. The well-screen **1** is surrounded by a gravel pack **3**, which is contained by a wellbore casing **5** and cement **8**. Perforations **6** in the

wellbore casing allow gravel to be distributed outside the wellbore to the desired interval. The number and placement of perforations are chosen to facilitate effective distribution of the gravel packing outside the wellbore casing to the interval that is being treated with the gravel-slurry.

[0010] One problem associated with gravel packing, especially with gravel packing long or inclined intervals, arises from the difficulty in completing packing the annulus between the screen and the casing for in-casing gravel packs or between the screen and the side of the hole for open hole or under-reamed gravel packs. Incomplete packing is often associated with the formation of sand "bridges" in the interval to be packed which prevent placement of sufficient sand below that bridge, for top down gravel packing, or above that bridge, for bottom up gravel packing. The problem associated with bridge formation is often circumvented by using alternate path technology, which provides separate pathways for sand laden slurry to reach locations above or below the sand bridge or bridges.

[0011] If the sand screen is damaged or impaired, sand infiltration may result causing flow impairment. Flow impairment during production from subterranean formations can result in a reduction in well productivity or complete cessation of well production. This loss of functionality may occur for a number of reasons, including but not limited to, migration of fines, shales, or formation sands, inflow or coning of unwanted fluids (such as, water or gas, formation of inorganic or organic scales, creation of emulsions or sludges), accumulation of drilling debris (such as, mud additives and filter cake), mechanical damage in sand control screen, incomplete

gravel pack, and mechanical failure due to borehole collapse, reservoir compaction/subsidence, or other geomechanical movements.

[0012] Current industry well designs include little, if any, redundancy in the event of problems or failures resulting in flow impairment from well-screen failure. In many instances, the ability of a well to produce at or near its design capacity is sustained by only a "single" barrier to the impairment mechanism (for example, screen for ensuring sand control in unconsolidated formations). In many instances the utility of the well may be compromised by impairment occurring in a single barrier. Therefore, overall system reliability is very low. Flow impairment in wells frequently leads to expensive replacement drilling or workover operations.

[0013] The current industry standard practice utilizes some type of sand screen either alone or in conjunction with artificially placed gravel packs (sand or proppant) to retain formation sand. All of the prior art completion types are "single barrier" completions, with the sand screen being the last "line of defense" in preventing sand from migrating from the wellbore into the production tubing. Any damage to the installed gravel pack or screen will result in failure of the sand control completion and subsequent production of formation sand. Likewise, plugging of any portion of the sand control completion (caused by fines migration, scale formation, etc.) will result in partial or complete loss of well productivity.

[0014] Lack of any redundancy in the event of mechanical damage or production impairment results in the loss of well productivity from single barrier completion designs. Accordingly, there is a need for a well completion apparatus and method to

protect the wellbore from gravel pack infiltration in the event of mechanical damage to the well screen. This invention satisfies this need.

Summary

[0015] A wellbore apparatus is disclosed. The wellbore apparatus comprises, an outer permeable material, a first basepipe section wherein at least a portion of the basepipe is perforated, the first basepipe is inside the outer permeable material and at least part of the perforated basepipe is designed to be adjacent to a production interval, and a second basepipe section wherein at least a portion of the second basepipe is slotted, the second basepipe is inside the outer permeable material and above the perforated basepipe section designed to be adjacent to the production interval wherein at least a portion of the slotted basepipe is designed to be adjacent to a non production section of the wellbore, and the first and second basepipes providing a three-dimensional surface defining a fluid flow path through the wellbore.

[0016] A second wellbore apparatus is also disclosed. The apparatus comprises an outer permeable material, a perforated basepipe section inside the outer permeable material wherein at least part of the perforated basepipe is designed to be adjacent to a production interval of a wellbore, a slotted basepipe section inside the outer permeable material and above the perforated basepipe section designed to be adjacent to the production interval wherein at least a portion of the slotted basepipe is designed to be adjacent to a non perforated section of the wellbore, and the perforated and slotted basepipes providing a three-dimensional surface defining a fluid flow path through the well.

[0017] A method of well completion is also disclosed. The method comprises providing a wellbore apparatus comprising, providing a wellbore apparatus comprising an outer permeable material, a first basepipe section with at least a portion of the basepipe is perforated, the first basepipe is inside the outer permeable material and at least part of the perforated basepipe is designed to be adjacent to a production interval, and a second basepipe section with at least a portion of the second basepipe is slotted, the second basepipe is inside the outer permeable material and above the perforated basepipe section designed to be adjacent to the production interval wherein at least a portion of the slotted basepipe is designed to be adjacent to a non production section of the wellbore, the first and second basepipes providing a three-dimensional surface defining a fluid flow path through the wellbore, and installing the wellbore apparatus in a wellbore wherein at least part of the perforated basepipe inside the outer permeable material is adjacent to a production interval and at least part of slotted basepipe inside the outer permeable material is adjacent to a non production section of the wellbore.

Brief Description Of The Drawings

[0018] Figure 1(a) is an illustration of a bare screen sand control completion;

[0019] Figure 1(b) is an illustration of a cased-hole gravel pack sand control completion;

[0020] Figure 1(c) is an illustration of an open-hole gravel pack sand control completion;

[0021] Figure 1(d) is an illustration of a Frac-Pack sand control completion;

[0022] Figure 2(a) is an illustration of an uncased production interval of a wellbore using an embodiment of the wellbore apparatus;

[0023] Figure 2(b) is a cross-section illustration of the wellbore apparatus of Figure 2(a);

[0024] Figure 3(a) is an illustration of a possible wellbore apparatus in a cased wellbore;

[0025] Figure 3(b) is a cross-section illustration of the wellbore apparatus of Figure 3(a);

[0026] Figure 4(a) is an illustration of an uncased production interval of a wellbore using an embodiment of the wellbore apparatus with alternate production flowpaths;

[0027] Figure 4(b) is a cross-section illustration of the wellbore apparatus of Figure 4(a);

[0028] Figure 5(a) is an illustration of a possible wellbore apparatus in a cased wellbore with alternate production flowpaths;

[0029] Figure 5(b) is a cross-section illustration of the wellbore apparatus of Figure 5(a).

Detailed Description

[0030] In the following detailed description, the invention will be described in connection with its preferred embodiments. However, to the extent that the following description is specific to a particular embodiment or a particular use of the invention,

this is intended to be illustrative only. Accordingly, the invention is not limited to the specific embodiments described below, but rather, the invention includes all alternatives, modifications, and equivalents falling within the true scope of the appended claims.

[0031] This invention discloses an wellbore apparatus for addressing gravel infiltration. The concept permits an outer permeable member or screen failure, by employing back-up media to retain gravel and form a stable gravel pack.

[0032] The apparatus comprises an outer permeable member in the wellbore with a slotted basepipe section and a perforated basepipe section inside the wellbore. At least a portion of the perforated basepipe section is adjacent to the wellbore and at least a portion of the slotted basepipe is above the production interval. The first and second basepipe provides a three-dimensional surface defining a fluid flow path through the wellbore.

[0033] Figures 2(a) illustrates an embodiment of the apparatus in an open-hole wellbore. Typically, as shown in Figure 2(a), a series or joints of screens **10** are placed in the wellbore. In open-hole completion, as shown in Figure 2(a), the outer permeable member shown as a top screen joint **10,** comprising a slotted basepipe **17,** is typically located near or above the casing shoe **13.** The lower outer permeable member shown as a screen joint **11** is typically located in the production interval against the open-hole pay sand **14.** Gravel packing material **18** is typically placed in the wellbore outside the outer permeable members **15.** Figure 2(b) is a cross section of the apparatus of Figure 2(a) in which the like elements to Figure 2(a) have been given like numerals. As shown in Figure 2(a) the outer permeable member **15** retains

the gravel packing material **18** from the basepipe **20**. The interior **25** of the basepipe **20** is a three-dimensional surface defining a fluid flow path through the wellbore. The interior **25** of the basepipe **20** is sometimes referred to as a production string. As shown in Figure 2(a), at least a portion of a basepipe with perforations **21** is located adjacent to the production interval **14** and at least a portion of the slotted **16** basepipe is located near or above a cased shoe **13** above the production interval **14**. Typically, as sown in Figure 2(a), the slots **17** are vertical but can be horizontal or slanted.

[0034] Figure 3(a) is an illustration of the wellbore apparatus with a perforated cased-hole completion interval that is similar to the embodiment of Figure 2(a) in which the like elements to Figure 2(a) have been given like numerals. In cased-hole completion, as shown in Figure 3(a) a top screen joint **10** is located near or above the top perforation and a lower screen joint **11** is located in the production interval with perforations **14**. In different embodiments there may be more than one top screen joint near or above the perforations **14**. Furthermore, there may be more than one lower screen joint below the top perforation.

[0035] The lower permeable member or screen joint **11** may be a commercially available gravel pack screens, for example, wire-wrapped screen or mesh type screen. In this embodiment, inside the lower screen **11** is a perforated basepipe. The perforated hole size **21** is preferable large enough to allow gravel freely passing through. The top screen joint **10** contains a slotted basepipe **17** covered by a permeable media **15**. The slot openings **16** on the basepipe are sized to be small enough to retain gravel and large enough to allow residual mud and formation fines freely passing through. Preferably, the slot number or density is large enough so that

the fluid flow friction is comparable or not much greater than the corresponding friction across the outer permeable media **15**. The top and lower screens may be connected by a coupling **19** on the basepipe such that the fluid could travel inside the basepipe between the two screen joints.

[0036] In one embodiment, alternate production flowpaths may be built into the apparatus to allow multiple flowpaths in the wellbore. Co-pending U.S. provisional application No. 60/459,151 discloses a Mazeflo device wherein multiple flowpaths are provided. U.S. Provisional Application No. 60/459,151 is hereby incorporated by reference.

[0037] One example of a multiple flowpath embodiment would be to provide enough spacing between the perforated and slotted basepipes and the outer permeable member to form a second fluid flow joint. A flow joint is a separate three-dimensional surface defining a fluid flow path through the wellbore. Figure 4(a) is an illustration of a multiple flowpath apparatus incorporating the Mazeflo design wherein the like elements to Figure 2(a) have been given like numerals. In this embodiment the well-screen **15** is a continuous well-screen providing a second flow path **41** for production fluid through the wellbore. The first flow joint **10** for fluid production is inside the slotted **17** and perforated basepipes **22**. In this embodiment the slots **16** and perforations **21** provide the permeable connection between the first and second flow joints and the weld joints **19** provide the section of separate flow within the second flow joint **41**. The slotted and perforated basepipes can also be engineered to have impermeable solid sections and allow a variety of flow paths between the first and the second flow joints.

[0038] Figure 4(b) is a cross-section of Figure 4(a) wherein like elements to Figure 4(a) have been given like numerals. As shown in Figure 4(b) two distinct flow joints are available in this embodiment. The flow joint inside the basepipe is the first flow joint **43** and the area between the well-screen and basepipe forms the second flow joint **41**. Additional flow joints can be created by the placement of additional basepipes, baffles and walls inside the wellbore. The additional flowjoints would provide redundancy permitting production of hydrocarbons despite sand infiltration from a sand-screen failure.

[0039] Figure 5(a) is an illustration of a multiple flowpath apparatus in a cased wellbore incorporating the Mazeflo design wherein the like elements to Figure 4(a) have been given like numerals. In this embodiment, at least a portion of the perforated basepipe **22** is adjacent to cased perforated **14** production interval and at least a portion of the slotted basepipe **17** is adjacent to the cased interval above the top perforation **14**. Figure 5(b) is a cross section of Figure 5(a) that is similar to Figure 4(a) wherein similar elements are given like numerals. As shown in Figure 5(b), the continuous sand-screen **10** provides a second flow joint **41** with the inside of the basepipe **20** providing the first flow joint **43**.

[0040] In one embodiment, The apparatus may be installed as a completion device before gravel packing. After installation of the apparatus the well is then gravel packed using alternate path shunts or conventional gravel packing technology. The basepipe inside the apparatus can be utilized as a production string producing hydrocarbons through the wellbore from the subterranean production interval to the surface of the earth.

Example

[0041] During gravel packing, a slurry of mixing gravel in a carrier fluid is pumped into the annulus around both top and lower screens. As shown in Figure 3(a), after the carrier fluid leaks off into formations or screens, gravel pack **18** is formed in the annulus. In the cased-hole completions, gravel pack is also formed inside the perforations **14**. When the top screen joint of Figure 3(a) is nearly covered by the annular gravel pack, the pumping pressure increases rapidly due to the diminishing area available for fluid flow. The high slurry injection pressure may instantly shear off the top screen jacket at the welding area **20** or cause the wires of the screen **15** (if wire-wrapped screen is used) parting due to both shear/compression load and erosion. In either case, gravel will intrude through the outer media **15**. In conventional gravel pack completions, the top screen **10** is identical to the lower screen **11**. That is, the top screen failure would result in losing gravel through the perforated pipe.

[0042] In the current invention, the intruded gravel will be retained by the slots **16** and maintain a stable gravel pack and gravel reserve. Since the slotted pipe is much stronger than either the welding area **20** or the outer screen media **15**, as well as the slotted pipe has not been exposed to long period of slurry erosion, the high slurry pressure could be sustained until sand-out, the end of gravel packing job. U.S. Patent Nos. 4,945,991 and 5,113,935 disclose alternate path technology shunt tubes that can be attached to both top and lower screen joints. U.S. Patent Nos. 4,945,991 and 5,113,935 are hereby incorporated by reference. With alternate path technology, maintaining high slurry injection pressure at reduced pumping rate is important in allowing shunt tubes to pack all voids in the wellbore. A relatively void-free or

complete gravel pack promotes gravel pack longevity. The slots may be placed evenly over the entire basepipe in the top screen joint. The slots may also be placed on part, for example, the lower portion, of the basepipe to further enhance the mechanical strength in the basepipe of the top screen joint.

[0043] The slots are sized to retain gravel but allow free pass-through of residual mud and formation fines. During well production, the dominant flow path would typically in Figure 2(a) and Figure 3(a) be from open hole **14** or perforated interval **14** toward the lower screen **11**. Since the top screen joints, **10** are not primary production flow paths, slot plugging, if occurs although unlikely, will have minimum impact on well productivity.

[0044] The apparatus may utilize slotted basepipe in the top screen joint or all or part of screen joints above the casing shoe (open-hole) or above the perforated interval (cased-hole). The current invention provides a reliable and forgiving apparatus and method to resolve gravel loss caused by screen damage during gravel packing. When the apparatus is applied to the field, the current screen manufacturing process and field operation procedures remain unchanged.